

RELATIONSHIP OF PRECIPITATION TO VORTICITY AND VERTICAL MOTION AT SALT LAKE CITY, UTAH

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ABSTRACT

An empirical study was made of the relationship of precipitation occurrence to linearly interpolated concurrent vertical motion, 500-mb. initial vorticity, vorticity advection, and the average of the 700-mb. and 500-mb. dew point depressions at Salt Lake City, Utah. All parameters except dew point depressions were obtained from the facsimile charts transmitted by the National Meteorological Center at Suitland, Md. Correlation between the three NMC computed parameters and observed precipitation was not as good as the correlation between dew point depression and precipitation. However, initial vorticity combined with vorticity advection resulted in a much better correlation with precipitation occurrence than did either parameter alone.

1. INTRODUCTION

In 1958, Sassman and Allen [1] made an investigation of the relationship of precipitation occurrence to vertical velocities as computed by the National Meteorological Center (NMC), and average temperature-dew point depression at the surface, 850-mb., and 700-mb. levels. This study was for Albany, N.Y., Washington, D.C., and St. Louis, Mo. Since results indicated that their charts would be of forecast value at these locations, it was decided to determine if similar methods would be useful over the intermountain west where topography plays an important role with regard to precipitation. Also, investigations of this nature are in line with the recent trend toward maximum use of facsimile products, as received at field stations.

In addition to vertical velocity, the relationship of initial vorticity and vorticity advection to precipitation occurrence was also investigated.

2. PROCEDURES

Sassman and Allen, in their figure 1, used the total upward displacement in 24 hr. of the air moving past the station. They used computed vertical velocities at the beginning and end of the period, and an intermediate forecast vertical velocity at mid-period. Negative values were taken to be zero, with the total upward displacement determined from the positive velocities only, using linear interpolations between observations. A similar method was used in this study. However, a 12-hr. period was used instead of a 24-hr. period. The relationship of vertical velocity to precipitation was determined by use of "observed" vertical velocities at both the beginning and end of the period, thus bypassing prognostic errors.

Sassman and Allen used the average dew point depression at the surface, 850-mb., and 700-mb. levels as their moisture parameter. Previous local studies [2] have indicated that moisture at much higher levels is of prime significance for forecasting precipitation over the intermountain west. Therefore, the average of the 700-mb. and the 500-mb. temperature-dew point depression was used in this study.

3. DATA

Sassman and Allen's data indicated considerable difference in summer and winter upward displacement. Since summer precipitation over the western plateau is nearly always of the convective thunderstorm type, the present study was confined to late fall, winter, and early spring. The period October 1961 through April 1962 was used for development purposes, and the period January through April 1961 was set aside for testing. Vertical motions were computed at NMC by Thompson's [3] two-level baroclinic model throughout these periods, except for an approximately 2-week interval at the beginning of March 1962 when Cressman's [4] three-level baroclinic model was in use.

4. RESULTS

Figure 1 shows the joint relationship between 12-hr. upward motion, average of the 700-mb. and 500-mb. dew point depressions, and the occurrence of measurable precipitation at Salt Lake City. The unit of upward displacement is hundreds of meters and the scale is logarithmic above 100 m. The net upward motion is computed from NMC vertical velocities at the beginning and end of the 12-hr. period, while the dew point depression

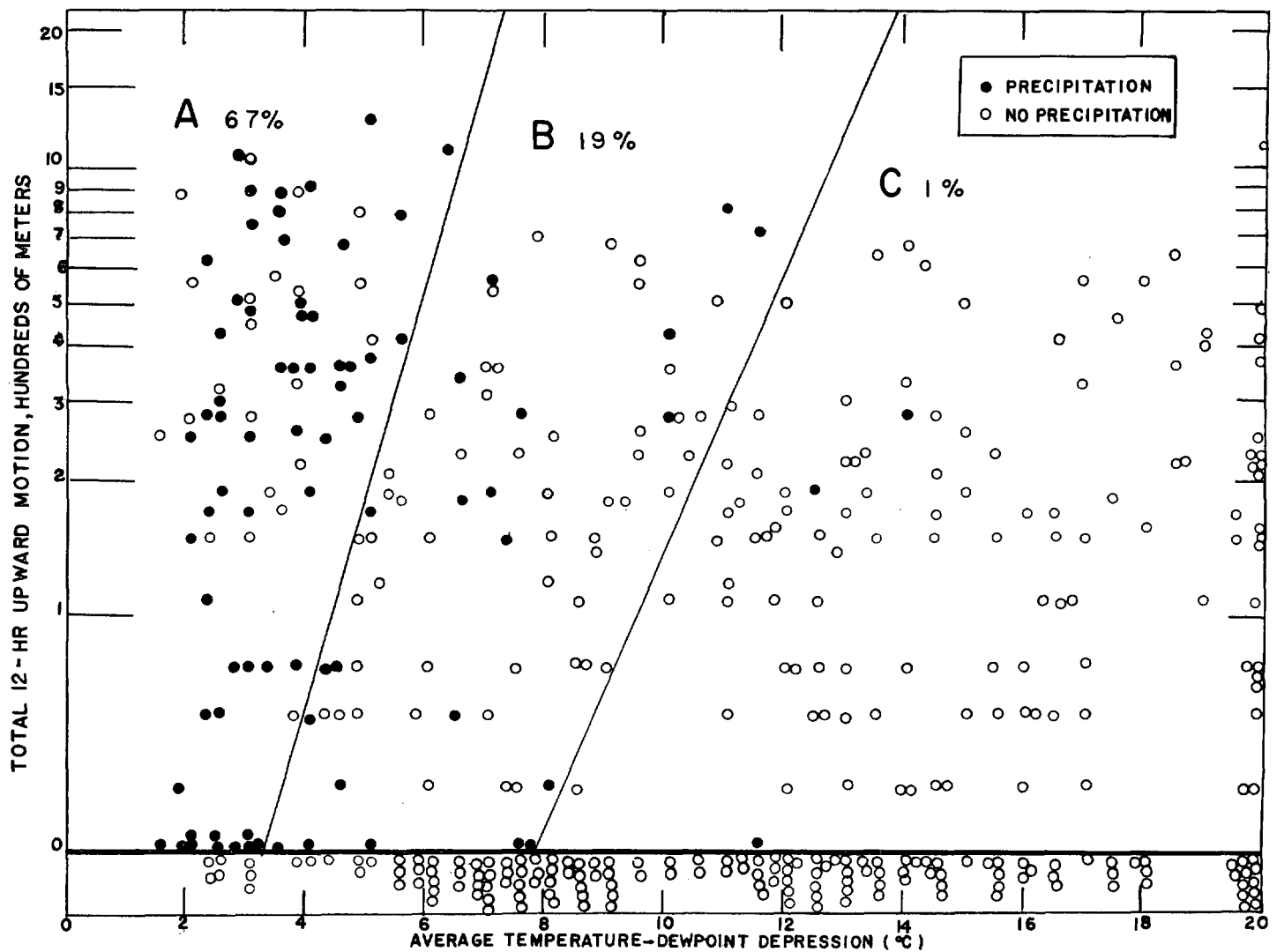


FIGURE 1.—Relationship between 12-hr. total upward motion, average 700-mb. and 500-mb. dew point depressions, and the occurrence of measurable precipitation at Salt Lake City. October 1961 through April 1962.

is at the beginning of the period. The chart is divided into three areas (A, B, and C) which show precipitation occurrence to be 67 percent, 19 percent, and 1 percent respectively. It may be seen from the slope of the lines that most of the correlation is due to the moisture parameter. Sassman and Allen's figure 1 shows much better correlation between vertical motion and precipitation occurrence. This result is rather to be expected, as large-scale vertical motions should be better correlated with weather over relatively flat country than over mountainous territory.

Plotting the 1961 test data on figure 1 gave 72 percent, 17 percent, and 5 percent precipitation occurrence respectively for the three areas, A, B, and C. These results are essentially the same as those of the development data.

Table 1 summarizes the relationship between the 12-hr. total upward motion and precipitation occurrence at Salt Lake City. Although the relationship could be considered a useful forecast tool, it still leaves a lot to be

desired. Studies by Wallington [5] and Wilson [6] showed relatively poor correlation between numerically computed vertical velocities and precipitation occurrence.

5. ADDITIONAL INVESTIGATIONS

In addition to total upward displacement computed from NMC vertical velocities, as used in the comparison

TABLE 1.—Relationship between total upward motion and precipitation occurrence at Salt Lake City

Total upward motion (10's meters)	Number of cases	Number of precipitation occurrences	Percent of cases with precipitation
>60.....	25	14	56
41-60.....	28	8	35
21-40.....	63	19	30
11-20.....	71	11	16
1-10.....	63	13	21
0.....	165	16	10
All cases.....	415	81	19.5

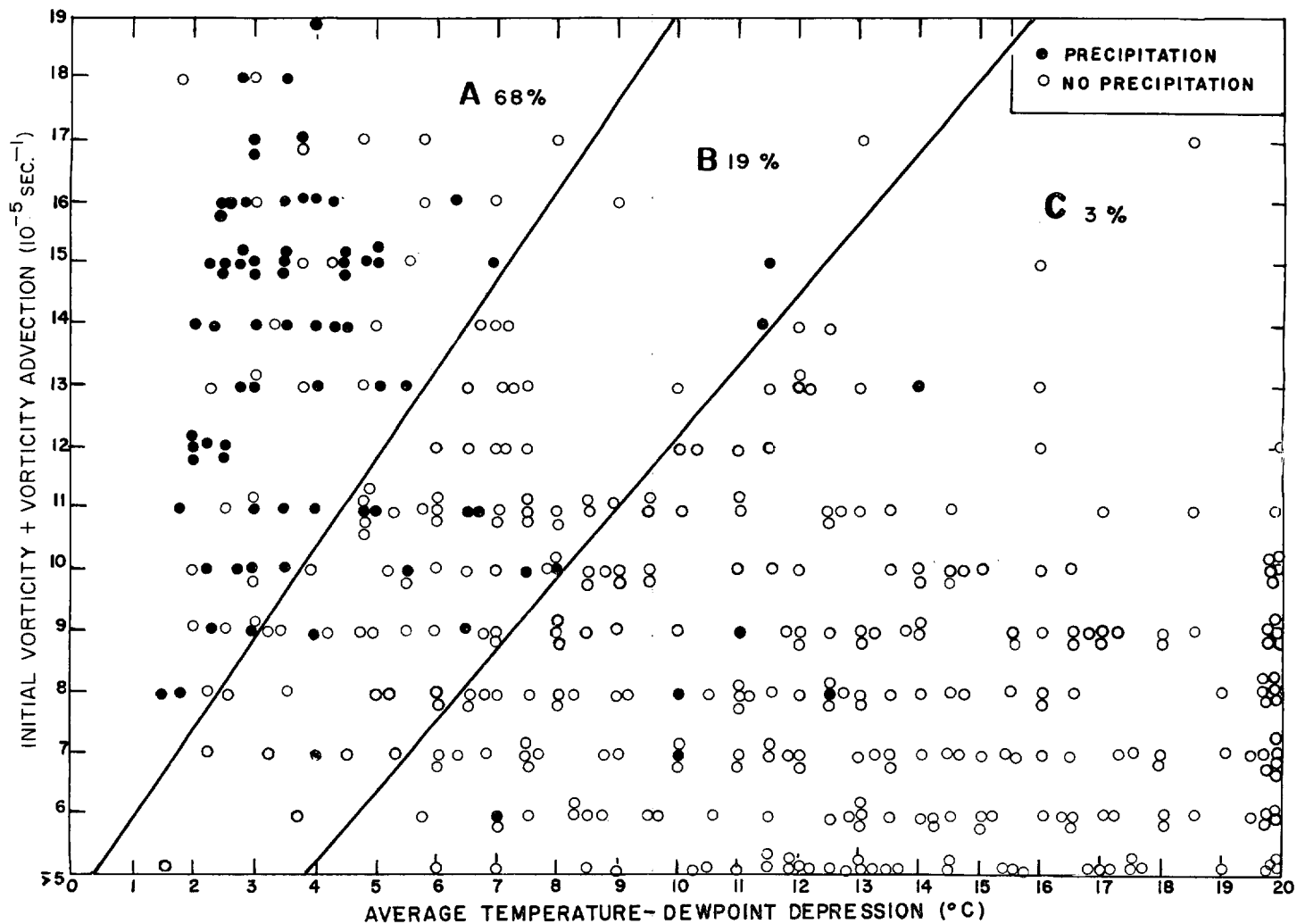


FIGURE 2.—Relationship between initial vorticity plus vorticity advection, average 700-mb. and 500-mb. dew point depressions, and the occurrence of measurable precipitation at Salt Lake City. October 1961 through April 1962.

with Sassman and Allen's earlier work, the relationship between initial vorticity and vorticity advection, as shown on NMC facsimile charts, and precipitation occurrence at Salt Lake City was also studied. Jenrette [7] has made a similar study for Chanute Field, Ill., and Dunn [8] has made a test of these relationships for Washington, D.C. The initial vorticity was taken directly from NMC charts at the beginning of the 12-hr. period during which the precipitation was measured. The 12-hr. indicated vorticity advection, for purposes of this study, was computed by taking 80 percent of the Salt Lake City observed 500-mb. velocity (as an approximation to the wind velocity at 600 mb., which is generally assumed to be nearer the level of non-divergence) and then measuring an appropriate distance upstream along the 500-mb. contours. The difference between the upstream vorticity, thus determined, and the current vorticity at Salt Lake City gave the vorticity advection. As with the vertical motion computations, NMC prognostic chart errors were bypassed by using vorticity computed from actual observed 500-mb. charts only.

Tables 2 and 3 show the relationship between measurable precipitation occurrence and vorticity advection and initial vorticity, respectively. The relationships are of the same order as shown in table 1 for total upward motion. However, table 4 shows the relationship between vorticity advection and initial vorticity combined by simple addition, and precipitation, and there is a very marked improvement. There are now 49 cases with 65 percent precipitation occurrence, and 37 cases with zero

TABLE 2.—Relationship between vorticity advection and precipitation occurrence at Salt Lake City

Vorticity advection (10^{-5} sec^{-1})	Number of cases	Number of precipitation occurrences	Percent of cases with precipitation
$\geq +5$	14	8	57
$+3, +4$	56	17	30
$+2, +1$	135	30	22
0.....	89	19	21
$-1, -2$	80	4	5
< -3	41	3	7
All cases.....	415	81	19.5

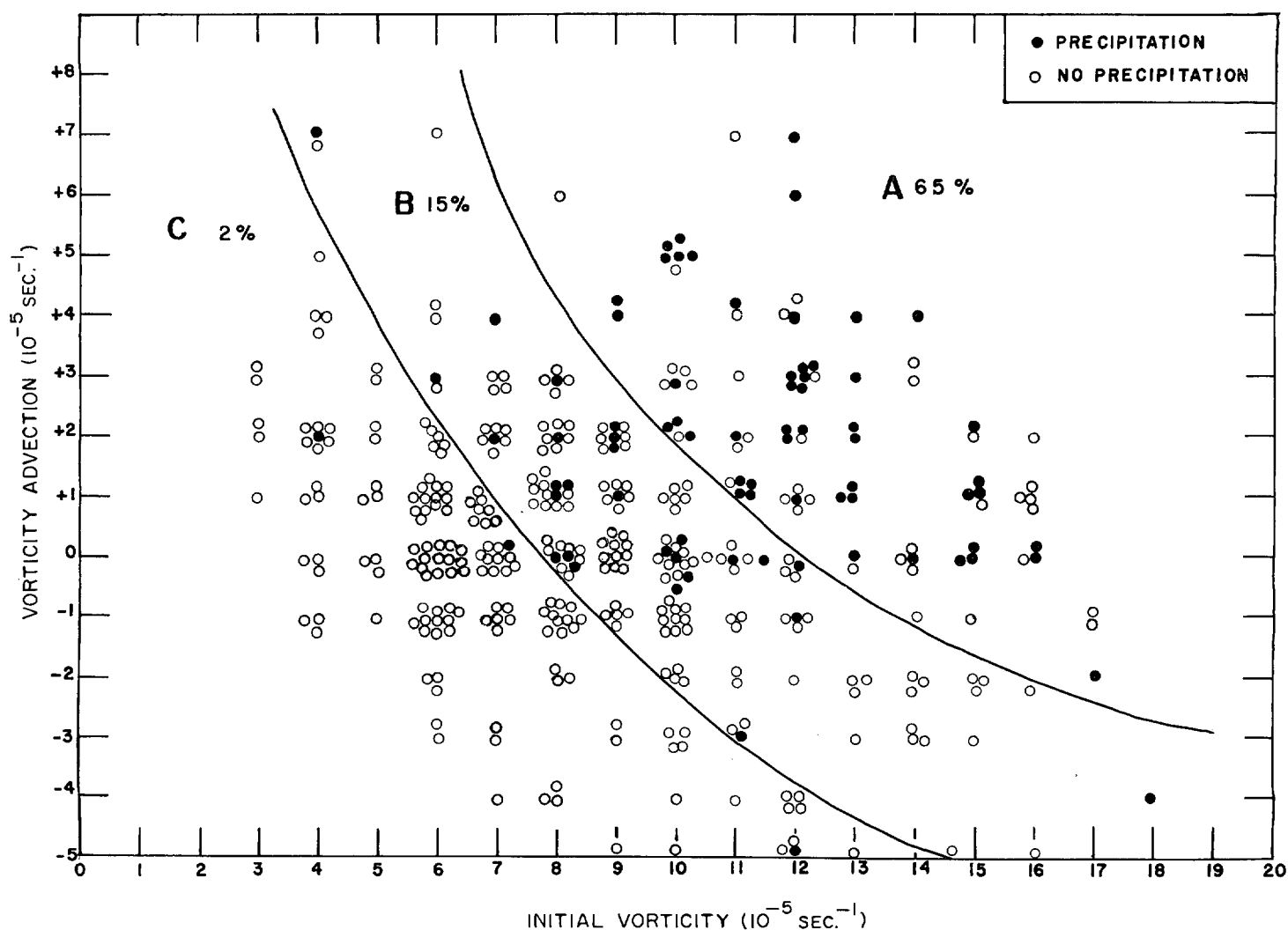


FIGURE 3.—Relationship between initial vorticity, vorticity advection, and the occurrence of measurable precipitation at Salt Lake City October 1961 through April 1962.

precipitation occurrence at the other end of the scale, with a total of 138 cases averaging only a 5 percent precipitation occurrence. This could be considered a very useful forecast parameter, providing NMC could make good prognoses of vorticity patterns.

Figure 2 shows the joint relationship between the average of the 700-mb. and 500-mb. dew point depressions, the initial vorticity plus vorticity advection, and precipitation occurrence. The three areas, A, B, and C, show precipitation occurrence of 68 percent, 19 percent, and

3 percent respectively. The slope of the lines indicates that the combined vorticity parameter plays an important part in determining the occurrence of precipitation. The same areas for the test data gave 68 percent, 25 percent, and 6 percent precipitation occurrence, indicating considerable stability in the procedure.

Figure 3 shows precipitation occurrence plotted against initial vorticity and vorticity advection. Areas A, B, and C have 65 percent, 15 percent, and 2 percent precipitation occurrence, respectively. The relationship is quite

TABLE 3.—Relationship between initial vorticity and precipitation occurrence at Salt Lake City

Initial vorticity (10^{-5} sec. $^{-1}$)	Number of cases	Number of precipitation occurrences	Percent of cases with precipitation
>14.....	30	13	43
12-14.....	71	27	38
9-11.....	122	27	22
6-8.....	149	12	8
<6.....	43	2	5
All cases.....	415	81	19.5

TABLE 4.—Relationship between initial vorticity plus vorticity advection and precipitation occurrence at Salt Lake City

Vorticity advection + initial vorticity (10^{-5} sec. $^{-1}$)	Number of cases	Number of precipitation occurrences	Percent of cases with precipitation
>14.....	49	32	65
12-14.....	54	22	41
9-11.....	137	20	15
6-8.....	138	7	5
<6.....	37	0	0
All cases.....	415	81	19.5

strong, considering the fact that no moisture factor is involved. However, the same lines drawn on plotted test data gave 54 percent, 19 percent, and 2 percent for areas A, B, and C. This is rather a sharp drop for area A, and possibly indicates a lack of stability in the relationship.

For categorical forecasts, the lines separating areas A and B were considered to be the 50 percent probability lines for precipitation occurrence. Therefore, precipitation was forecast for cases falling in area A of each figure, and no precipitation for areas B and C. Percent hits for figures 1, 2, and 3 were 87 percent, 89 percent, and 84 percent respectively. Test data gave 88 percent, 86 percent and 78 percent respectively, for the three figures.

6. CONCLUSIONS

Correlation between NMC computed vertical motion, vorticity advection, initial vorticity, and precipitation occurrence was not as good as the relationship between dew point depression and precipitation occurrence. This is understandable, as precipitation naturally correlates very highly with any moisture parameter on a concurrent basis, and the difficulty, of course, comes in trying to forecast the moisture parameter. The temperature-dew point spread is used here primarily as a basis for comparison with the NMC vorticity and vertical motion parameters.

It is encouraging to note that vorticity advection combined with initial vorticity showed a strong enough relationship with precipitation occurrence to be quite useful from a forecasting standpoint. There were several cases of precipitation occurrence with negative vorticity advection as shown by NMC charts. Most of these were cases of precipitation associated with warm fronts or overrunning situations.

Further investigations along these lines could possibly lead to fruitful results, such as distinguishing between vorticity maxima that are associated with the main body of vorticity, and those that are merely a breakoff from the main vorticity center; making use of the initial association between vorticity and current weather; and the relationships between vorticity and 12-hr. surface

pressure changes and stability index. Descending vertical motion as a factor in ending precipitation in progress should also be studied. Complications arise in mountainous terrain, as orographically induced vertical velocities are known at times to exceed large-scale vertical motion. Reference [8] includes some factors, particularly temperature advection, that could be studied in detail with respect to precipitation occurrence.

It is also planned to study the relationships shown in tables 1 through 4 using NMC vorticity prognostic charts instead of observed charts. The purpose here would be to assess the value of actual prognostic charts as compared to the "perfect" prognostic relationships developed in the above tables.

ACKNOWLEDGMENTS

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